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FACILITY FORM 602

N65-35281 (ACCESSION NUMBER)
(THRU)
9 (PAGES)
1 (CODE)
TMX-51652 (NASA CR OR TMX OR AD NUMBER)
14 (CATEGORY)

A TWO-PLANE SIX-COMPONENT BALANCE

NASA-TMX 51652

by

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GPO PRICE $ ______

CSFTI PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

Presented at the Twenty-First Semi-Annual Meeting
of the Supersonic Tunnel Association

Princeton, New Jersey
April 6-7, 1964

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INTRODUCTION

The internal strain gage sting balances used in wind tunnels are of two general types:

1) The "Floating Frame" type, in which the forces are transmitted from the model support to the ground support through a number of pivoted elements. Each element provides designed stiffness to the force component to be measured by it and is relatively compliant to all other force components.

2) The "Compound" type, in which forces are transmitted from the model to the ground support through a number of elements in series. This type is sometimes referred to as "Solid" or "Single Piece" due to its construction.

The "Floating Frame" balances are often more desirable because of their high stiffness and low interactions. However, present balances of this type are expensive and difficult to design, fabricate, and assemble. Some of the complexity of the present balances has been necessary in order to minimize temperature errors. A modified version of the "Floating Frame" type balance was therefore designed and developed at Ames to overcome some of these limitations. In addition to being easy to fabricate and assemble the new type balance has the further very desirable feature that it allows passage of leads or other devices through its central portion. Low temperature error in axial force results from the arrangement of all the force sensing elements essentially in only two cross-sectional planes of the balance, hence the name "two-plane balance."

DESCRIPTION OF BALANCE

A 2-1/2-inch-diameter two-plane balance has been built and calibrated for the following design loads.

Normal front and Normal rear	1000 lb each	(453 KG)
Side front and Side rear	1000 lb each	(453 KG)
Axial	300 lb	(13.6 KG)
Rolling Moment	2000 in.-lb	(23 KGM)

The balance (Figs. 1 and 2) is approximately 13-1/4 inches in overall length. It consists of a 2.5 inch O.D. outer sleeve, 10 inches long, attached at its two extremities by means of pins to an inner hollow cylindrical support approximately 1-3/4 inch O.D. and 1 inch I.D. The support is attached to the sting while the central portion of the outer sleeve supports the model. The aerodynamic forces and moments are transmitted from the "floating" center portion of the outer sleeve to the inner support through eight links symmetrically arranged, four each, in two parallel

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planes eight inches apart and perpendicular to the longitudinal axis of the balance. The links are each 0.13 inch square by 0.75 inch long obtained by cutting slots in the outer sleeve in proximity to the points of attachment with the inner support.

A developed view of the cylindrical outer sleeve is shown in Fig. 3. The links which transmit the applied forces from the central portion of the outer sleeve to the supported ends are marked 1 to 8. The interconnecting slots are arranged so as to place the normal force links 1 and 7 in tension while links 3 and 5 are in compression, under the action of positive (upward) normal forces. Similarly, under the action of positive side forces, links 2 and 8 are in tension while links 4 and 6 are in compression. The column type strains induced in the links are utilized to measure normal forces, side forces, and rolling moment. (See Fig. 4.) The axial force causes bending of the links as double cantilever beams. The normal, side-force, and rolling-moment gages are placed on the zero axis of the moment distribution due to the axial force; therefore there should be no interaction of axial force on normal force, side force, or rolling moment. Interactions of normal and side forces on axial force cancel out in the bridge circuit, interactive effects being the same in adjacent arms of the bridge. Reactions due to rolling moment, unlike those due to normal and side forces, do not cancel out in the axial force bridge; consequently, there exists an interaction of rolling moment on axial force. This interaction is proportional to the rolling moment; therefore, a constant portion of the moment bridge output voltage is used to cancel this interaction on axial force. The actual measured interactions are shown in Table I.

ADVANTAGES

This balance type has the following major advantages:

a) Balance stiffness is maximized, since attachments and link flexures are virtually eliminated.

b) The machining and fabrication costs are low (comparable to "solid type" balances).

c) The hollow inner support permits the passage of leads through the balance.

d) The design provides alinement in construction as in a "solid type" balance and care required for assembling is not as critical as that required for other "floating frame" balances.

e) Temperature effect on axial force is found to be small owing to the two-plane arrangement.

f) Interactions are low.

g) As shown in figure 5, permissible loadings are flexible, allowing increase in normal and side loads when axial load is low, and vice versa, without exceeding allowable maximum stresses in the gage links.

DISADVANTAGES

Some of the disadvantages of this type are:

a) Since the design of balance utilizes the stress distribution for load component measurement, the gage placement is critical.

b) Support strength and space requirements for gage separation limit the minimum size of balance that can be designed.

BALANCE CAPACITY

NORMAL FORCE-FRONT	1000 lb
-REAR	1000 lb
SIDE FORCE-FRONT	1000 lb
-REAR	1000 lb
AXIAL FORCE	300 lb
ROLLING MOMENT	4000 in-lb

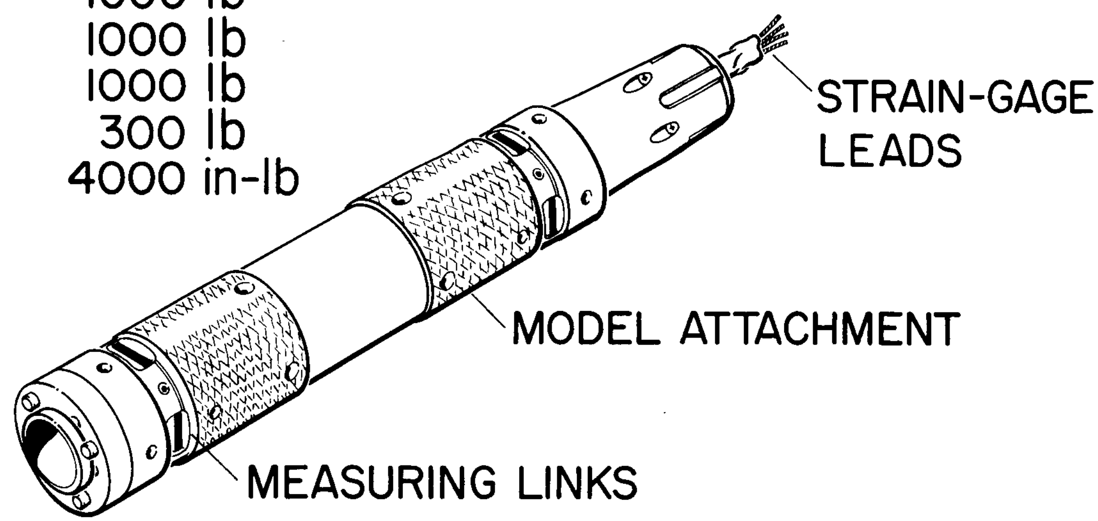

Figure 1.- Ames 2.5-inch two-plane balance.

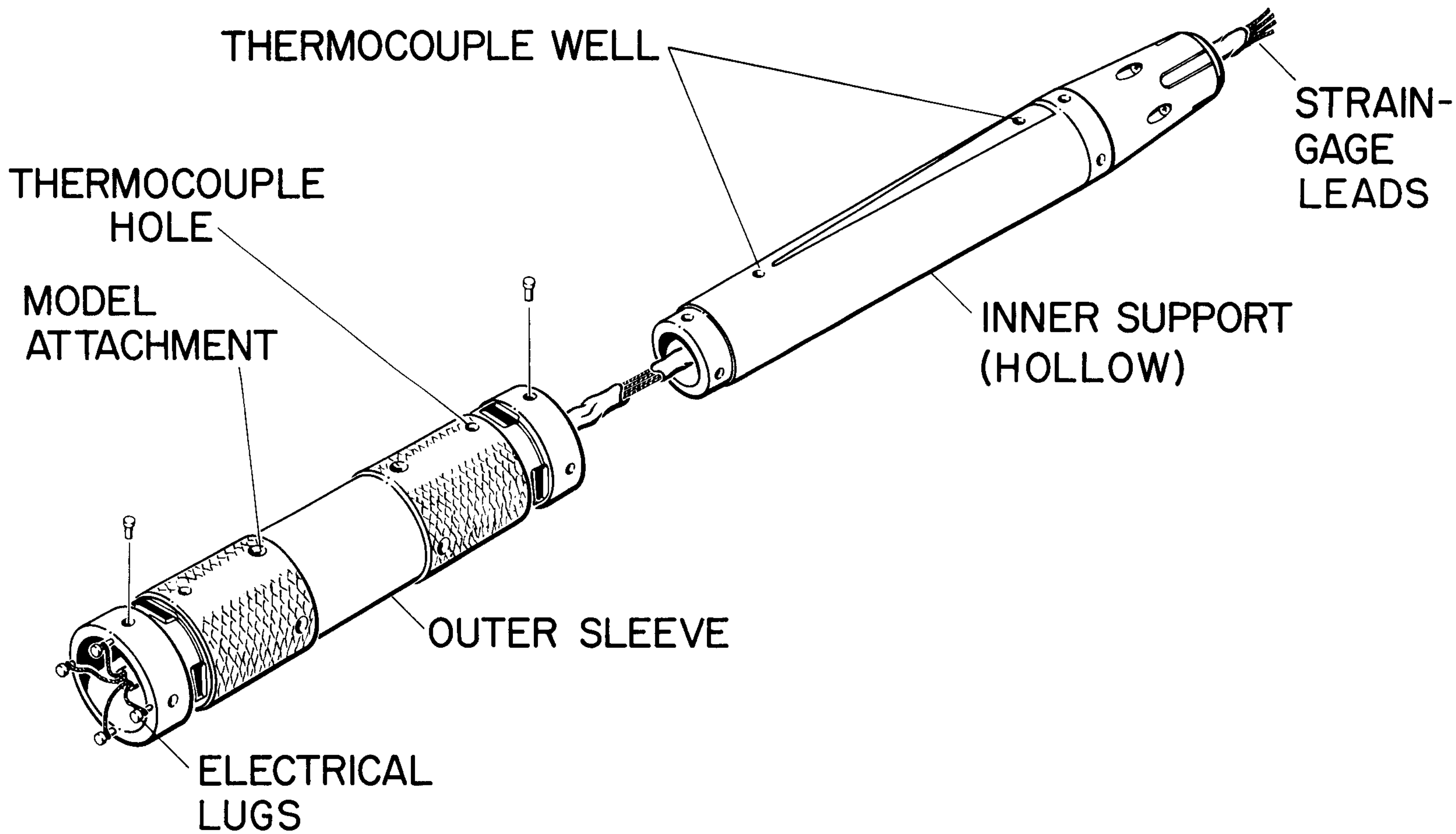

Figure 2.- Disassembled view of Ames 2.5-inch two-plane balance.

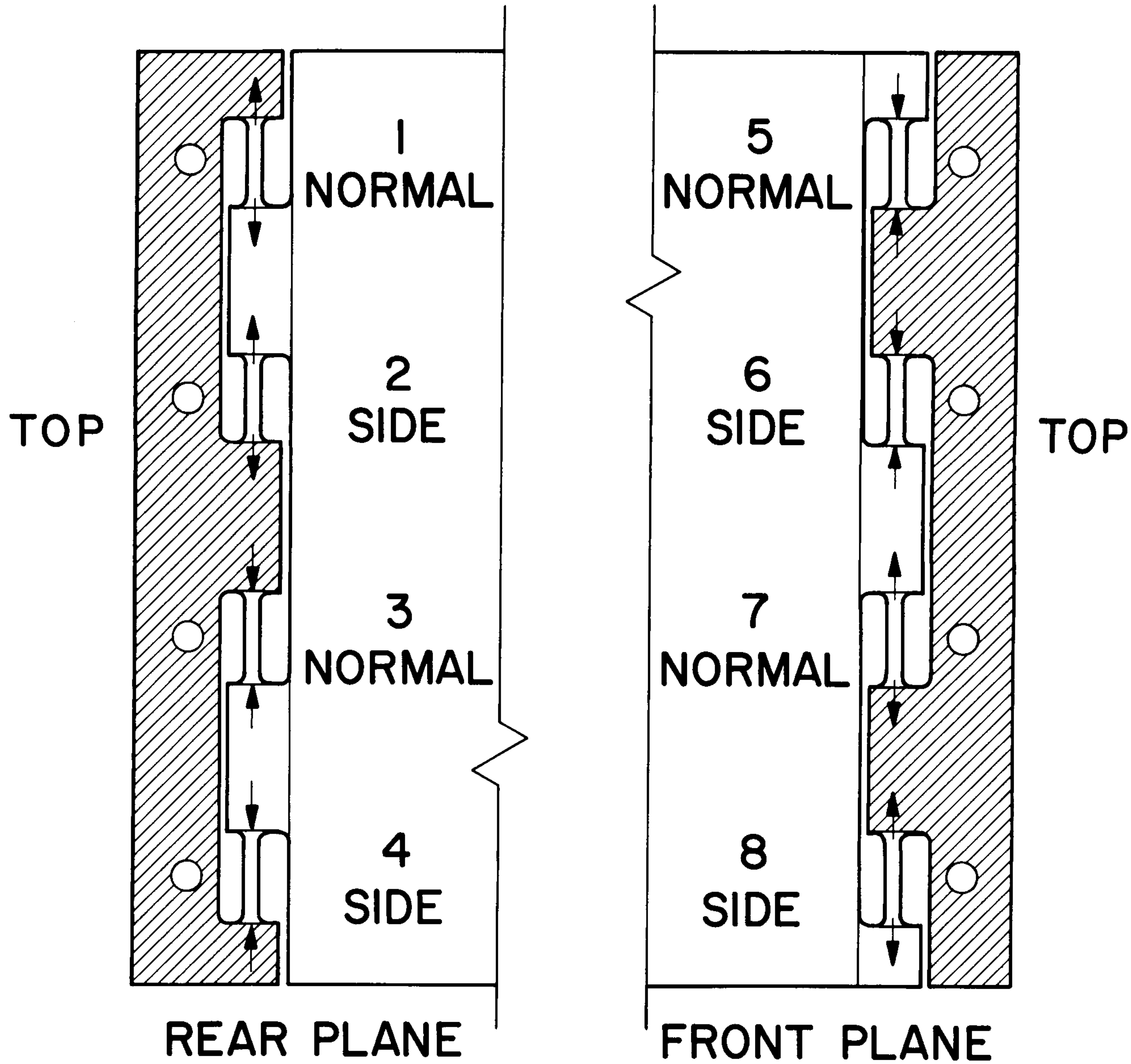

Figure 3.- Developed view of outer sleeve.

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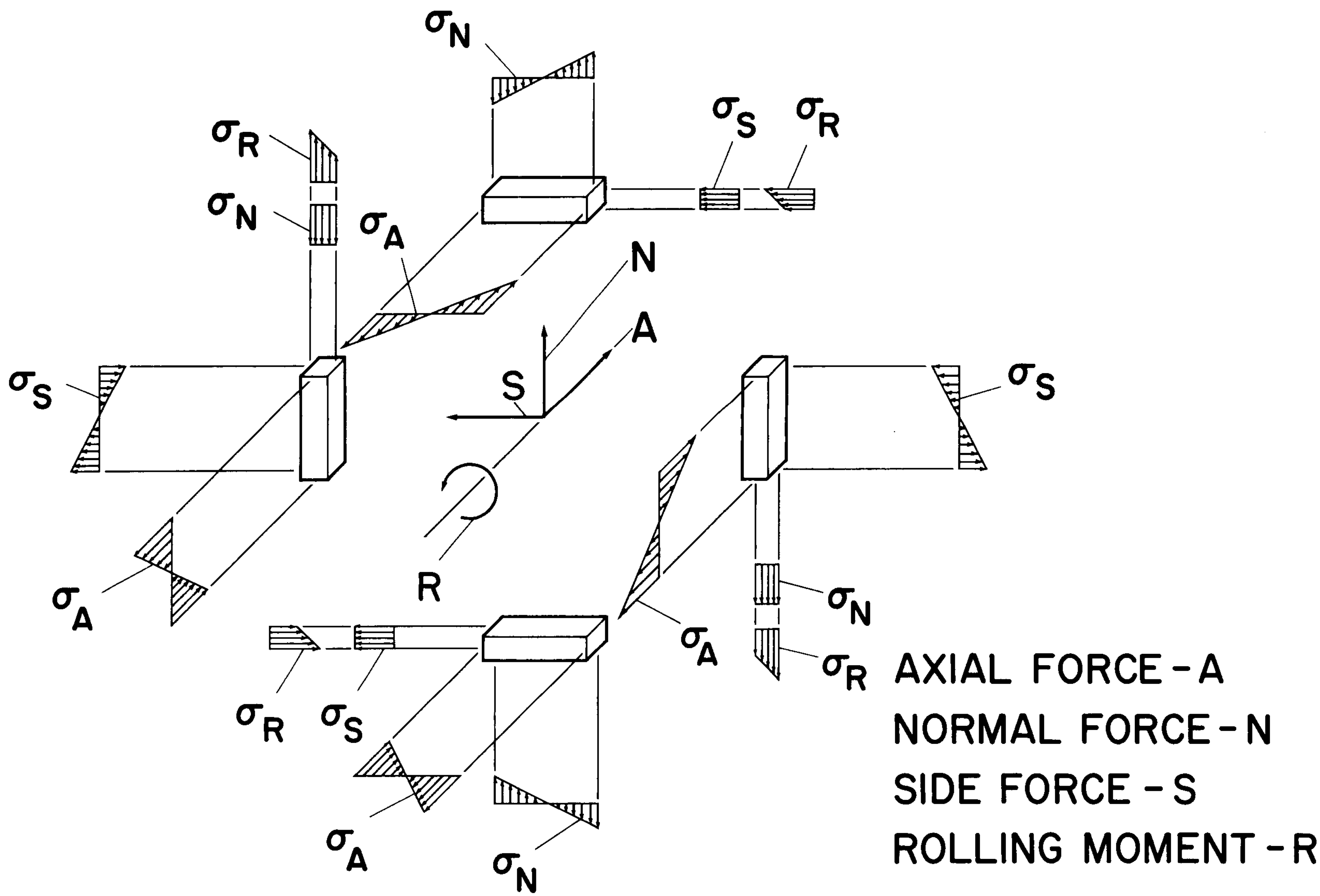

Figure 4.- Stress distribution on front force elements due to positive load configuration.

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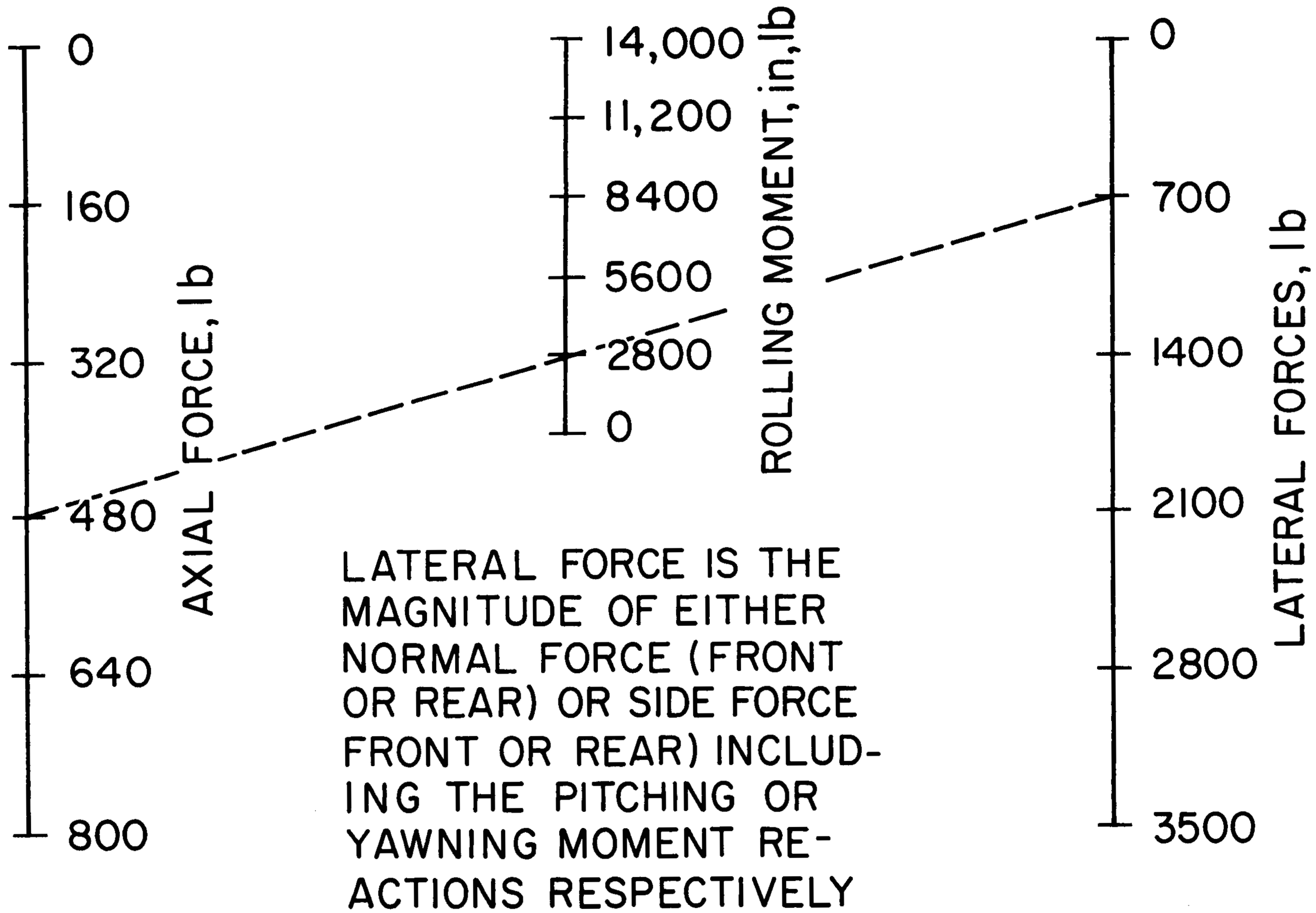

Figure 5.- Stress nomograph based on σ total = 100,000 psi.

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